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NONUNIFORM ELECTRICAL CONDUCTION IN MAGNETOHYDRODYNAMIC CHANNELS

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Abstract

Two methods of describing steady electrical conduction in a partially ionized gas with Hall effect, strong applied or magnetically induced electric fields, and non-uniform electrical conductivity have been proposed⁽¹⁾. These methods are elaborated upon and further results are obtained in the present study.

The first method is based upon the introduction of model conductivity distributions into Maxwell's equations and the Ohm's Law. Detailed solution for potential and current in the conducting gas may then be obtained. The second method incorporates the effect of a nonequilibrium electrical conductivity because of Joulean heating-induced nonequipartition of electron and gas temperature. Maxwell's equations and Ohm's Law are thus supplemented with the electron continuity and energy equations. The occurrence of such a nonequilibrium conductivity is shown to lead naturally to the possible development of a static instability previously discussed by Kerrebrock⁽²⁾ as well as a dynamic instability which occurs with large Hall effects in a nonequipartition plasma. This latter instability has been termed by Kerrebrock⁽³⁾ as an "electro-thermal wave instability." It is shown that the governing system of equations for steady nonuniform conduction is in general of mixed elliptic-hyperbolic type. In addition, when the electrons are in Saha equilibrium at the local electron temperature, the condition that the steady equations for nonuniform conduction be elliptic is shown to be the same as the condition that the time-dependent equations be stable. The implications of such stability and type considerations for numerical studies of steady nonuniform electrical conduction with a nonequilibrium conductivity are discussed.

These methods are applied to flowing gases in two-dimensional linear magnetohydrodynamic channels with segmented electrode structures. Detailed numerical solutions for current and potential are obtained. The effects of a large Hall parameter on the performance of an MHD generator with high or low conductivity layers over the electrodes and insulators are examined. In general, it is found that conductivity-induced nonuniformities lead to a degradation of performance of the generator which becomes more pronounced as the Hall parameter is increased.

Performance calculations have also been made for the nonequilibrium conductivity model. These calculations show the degradation of Hall voltage in a Faraday generator as increasing departures of electron and gas temperature are allowed. The effects of varying the Hall parameter are also examined subject to the condition that the Hall parameter not exceed a critical value which brings on the electrothermal wave instability.

References

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